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World Records: How Much Athlete? How Much Technology?

Jos J. de Koning

The quality of performance during international competitions such as the Olympic Games and various world championships is often judged by the number of world records attained. The simple fact that world records continue to improve is evidence that sports performance is progressing. Does this also mean that athletes are improving? Is the continual progression of world-record performances evidence that contemporary athletes are superior to the athletes who performed in the past? Technological developments may obscure insight into the athletic enhancement made by athletes over the years. This commentary tries to separate technological and athletic enhancement in the progression of world records by the use of a power balance model.

Keywords: performance, modeling, innovation, athletic equipment, speed skating

At the Olympic Winter Games of 1956 in Cortina d'Ampezzo, Italy, the gold medal in the 1500-m speed skating event was won, jointly, by the Russian skaters Yevgeniy Grishin and Yuriy Michaylov, with a world-record time of 2:08.6. They skated on a rink prepared on Lago di Misurina, at an altitude of 1754 m. At present, 15 Olympic Winter Games further in time, the world record has progressed (Figure 1a) and currently is held by Shani Davis from the United States in 1:41.04, skated at the Utah Olympic Oval, Salt Lake City, Utah, at an altitude of 1423 m, in a venue with many other world records. Is Davis really that much superior to Grishin and Michaylov? Historical images and film footage show that not only skating equipment has changed, but also skating style and the *intensity of racing*. A part of the 27.56-s improvement is clearly attributable to technological development. Presumably, a part is also attributable to the athletic enhancement of the skaters. Obvious technological improvements in speed skating include better preparation of the ice surface, aerodynamic racing suits, and the introduction of clap skates (Dutch, *klapschaats*).^{1,2} The effect of these technological innovations can be at least partially accounted for by modeling with power equations, which makes it possible to estimate the influence of each of these improvements on performance.^{3,4} An adjustment of past performances can thus be done to estimate what historical performances would be if corrected for technological improvements. In this way, the progress of world records can be evaluated with the current technological status as reference.

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The Model

The velocity of a skater is related to the power produced by the athlete and the power lost to the environment. The power produced is the aerobic and anaerobic energy systems adjusted for the efficiency of power transfer to propulsion. The power losses consist of losses to air and ice friction as well as changes in kinetic energy.^{1,4} The relation between velocity and power needed to overcome the air frictional force is nonlinear and depends on the aerodynamics of the skaters and their garments as well as on environmental circumstances. Studies on the aerodynamics of speed skating¹ have elicited detailed information on the effect of skating posture, anthropometry, type of clothing, altitude, and net air motion at the venue (eg, wind). These factors, except air motion at the venue, can be lumped together into the aerodynamic coefficient. The relation between velocity and power to overcome ice resistance is linear.⁵ Ice resistance depends on ice temperature, the method of ice preparation, and the type of skate blade used, and is accounted for in the coefficient of ice friction.

At a given magnitude of these coefficients, we can calculate the power demand for any skating velocity. Taking coefficients that belong to the contemporary situation (indoor oval, high altitude, aerodynamic suits, excellent ice preparation) and calculate the power demand to skate the world records that were set during the last 15 Olympiads (Figure 1b), we get an underestimation of the actual power output necessary for skating each record. Technological development has reduced the values for the aerodynamic coefficient and the coefficient of ice friction over the years, so a correction of these coefficients needs to be done to estimate the real power demand that belongs to each record. The altitude at which each record was skated also needs to be taken into account. With these values accounted for, the power output required to achieve the performances at the moment they were set can be estimated (Figure 1c).

With historical information about the location and altitude of world record rinks, the coefficients can be adjusted and the probable power output necessary to skate each record can be estimated. This power output can then be used as the basis for a recalculation of the historic 1500-m race with the power balance model to estimate the virtual time of historic world records, as if they were skated under the same circumstances as when the current world records were set. The progress from the corrected world records calculated with this procedure, reflect the technology-independent enhancement that the athletes have achieved (athletic enhancement; Figure 1d).

Technological Developments Made During the Past 50 Years

In the 1950s and early 1960s, speed skaters were dependent on Mother Nature when it came to ice conditions. International speed skating competitions were mainly held in Nordic countries, the United States, or Soviet Russia, often at altitude. Although natural ice can be very fast, the absence of artificial freezing made the preparation of the ice rink unpredictable. The introduction of refrigerated 400-m ice rinks and ice resurfacing machines reduced the coefficient of ice friction considerably (from 0.006 to 0.004)^{1,5}.

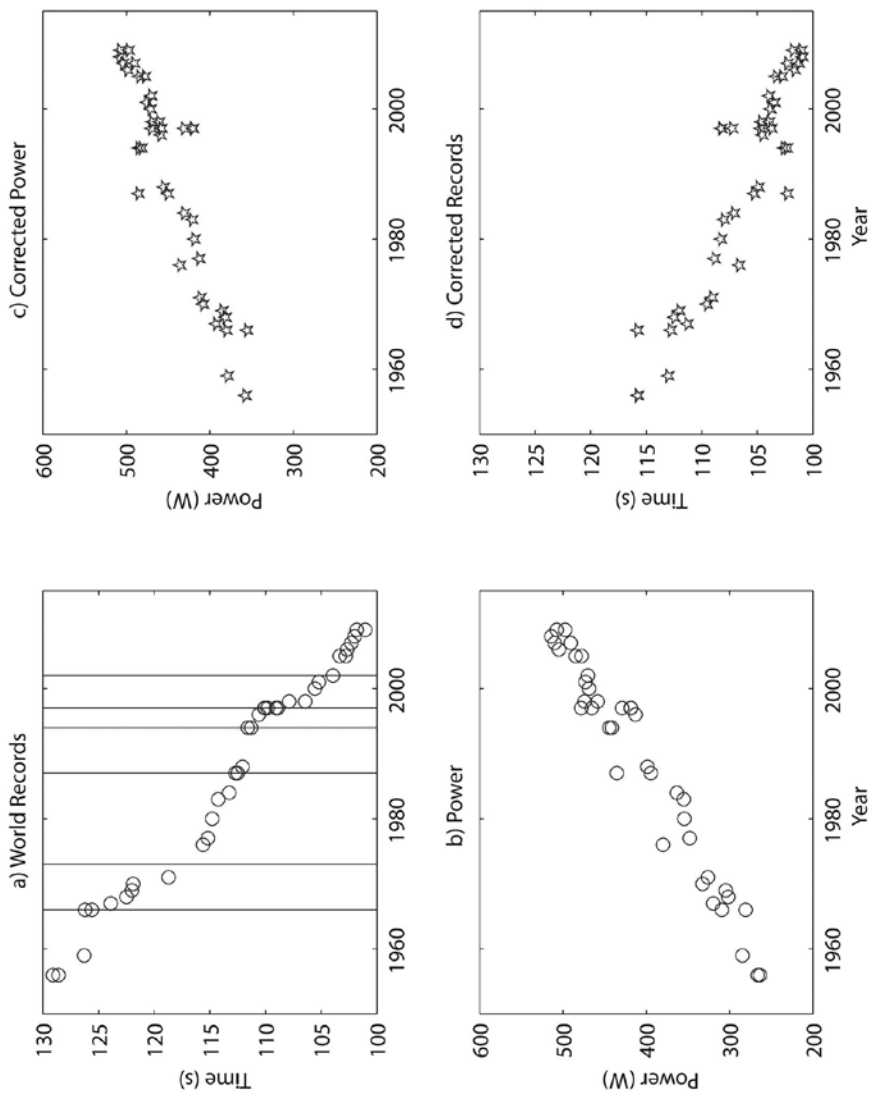


Figure 1 — (a) Progress in world-record 1500-m speed skating for men. Vertical lines indicate technological developments. (b) Estimated power output for the world records assuming contemporary technology and circumstances. (c) Corrected power output based on modeling results for technological developments. (d) World records corrected for technological developments.

A further reduction in the coefficient of ice friction (from 0.004 to 0.0035) was made possible by the introduction of fully covered 400-m ice rinks in 1987. From the mid-1990s, skaters had the availability of skate blades made from powdered metallurgic material. These skate blades reduced ice friction by another 30% (personal observation), to a contemporary value of 0.0025.

In the early days, speed skaters used knitted jerseys, tightly fitted pants, and often a woolen cap. This outfit was replaced in 1974 by one-piece suits made of Lycra-like material, form fitted to the body. These suits were improved in 2002 with the addition of selected smooth and rough patches for further reduction of air frictional forces. The traditional garment caused a 10.5% larger air friction coefficient than the current suits, and the latest improvement caused a reduction of 2%.¹

In the mid-1980s, the Dutch scientist Gerrit Jan van Ingen Schenau invented a skate with a hinge between the boot and the blade.^{1,6-9} The aforementioned clap skate is the most significant innovation in speed skating to date. With this skate, the athlete is able to generate a higher power output (12%) due to improved efficiency (for details, see refs. 7, 8, 9). When elite speed skaters began using this type of skate, every world record improved at least once within the first year of the introduction of the clap skate.

Model Calculations

With the knowledge of the above-described technological developments and the use of the power balance model, it is possible to estimate what the world records would have been if they were all skated under the same circumstances. Figure 1a shows the historic progress of the world records on the 1500 m; Figure 1b shows the power output required had they been skated with contemporary technology. These power output values are an underestimation of the power output of the skaters during historical world-record races because not all these innovations were available at the time of the races. Figure 1c illustrates the model estimations for the power output that the athletes must have produced at the time of their world-record performances. If this power output is then applied to contemporary conditions, Figure 1d would have been the current time for the historic world records.

The progress in performance illustrated in Figure 1d could then be seen as *real athletic improvement* of speed skaters over the last 15 Olympiads. This observation suggests that roughly half of the progress in world records comes from technology and the other half from real athletic improvement. However, published values of muscle power output and/or VO_2max in elite skaters have not changed meaningfully over this time period.^{2,10-13} Accordingly, it must be assumed that skaters have become more efficient over the same period of time, so that the net *skating* power output has increased despite little change in the *biological* power output. This seems to be reasonable in terms of the increase in the amount of specific skating training undertaken by contemporary skaters. The advent of professional teams and the availability of year-round indoor ice rinks have massively increased the total number of specific training hours. In the 1950s, it is likely that skaters could only skate during 3 mo of the year (approx. 60 skating days per year, often with practices abbreviated because of very harsh weather conditions). By 1980, with the advent of artificially cooled ice rinks, the number of skating days per year had perhaps increased to approximately 100 per year. Contemporary skaters rarely go a week

without skating and probably have >200 skating days per year. Specificity of training is probably a critical element, as speed skating is a highly complex motor task that must respond favorably to more specific training. The crouched position of speed skaters has a large influence on the blood flow and oxygenation of the leg muscles.¹³ Specific training could have an influence not only on the effectiveness of motor coordination patterns, but also on physiological adaptations. Traditionally, speed skating was a seasonal sport with a large amount of nonspecific summer training (running, weight lifting, plyometric exercises, and cycling). With the introduction of refrigerated and covered skating rinks, the amount of specific training has substantially increased. In addition, short track speed skating and in-line speed skating have become training modes and sources for an increasing talent pool. As recently as 1990, long track speed skaters would have scoffed at the concept of skating short track in the summer as a means of technique improvement. It can be assumed that these developments have influenced skating efficiency positively, although historic measurements of skating efficiency are not available for comparison. However, even the experimentally determined efficiency of contemporary elite speed skaters, values around 0.17^{2,7} are still low compared with cycling.

The increasing speed of the skaters through the years also influenced the skating style and racing style as well. Contemporary skaters bend their skate blades slightly for better skating in the turns, and their race strategy has a more all-out character. Because they are going faster, they can afford to go harder early in the race. Accordingly, the 1500-m race has become a long sprint. The luxury of using this all-out strategy has further contributed to the advancement of world records.

Some limitations in the way the model is used deserve mentioning. In the presented estimations, the individual variation in skating style was not included. Theoretically it would have been possible to include this if data on anthropometric parameters and skating position were known. Unfortunately, historic archival material is very limited, so it is difficult to adjust the model for these factors. The same holds for historic meteorological conditions. It must be assumed that during all world-record performances these variables were close to optimal. However, fans of skating can point out many examples of world records that occurred in less than ideal climatic circumstances, which suggests that our estimation of how fast historic athletes might have gone is still underestimated.

The corrected world records in Figure 1d show some extraordinary performances. The world record set by Gulyayev in 1987 (1:52.70) and the world records set by Ritsma and Koss in 1994 (1:51.60 and 1:51.29) corrected for technological developments are performances (1:42.3, 1:42.6, and 1:42.3 respectively) in the range expected for contemporary Olympic athletes. On the other hand, some records set in 1997, immediately following the introduction of the clap skate, turn out to be nonrecord performances when corrected for technological advantages. These skaters were perhaps lucky to be the first skaters of international level who dared to take advantage of innovative developments. However, in high-level sports, the courage to try innovative equipment is an admirable quality in its own right, so no disqualifying comments are intended toward these athletes.

In summary, it can be stated that the progress in 1500-m world records during the last 50 y can equally be attributed to technological developments and athletic improvement. The athletic improvement represents an approximately 25% increase in power output. However, when one considers that the increase in specific training

time has also increased markedly over the last 50 y and that estimates of skating efficiency are hard to correct for, it may not be unrealistic to suggest that the historic champions would compete very effectively under contemporary conditions. The present analysis was limited to responses in speed skating. However, we believe that the principles presented in this commentary might allow similar correction for historical performances in other sports.

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